NASA Facts

National Aeronautics and
Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, CA 91109

New Millennium Program

NASA's New Millennium program, a series of missions to test cutting-edge technologies never before flown, will pave the way for a 21st century fleet of affordable, frequently launched spacecraft -- perhaps 10 to 15 per year -- with highly focused science objectives.

New Millennium's Deep Space 1 will test ion propulsion and other technologies when the spacecraft flies by a comet (above) and an asteroid.

New Millennium will develop and validate the essential technologies and capabilities required for these new types of missions. The program is designed to initiate a revolutionary new way of exploring Earth, the solar system and astrophysical events in and far beyond the Milky Way galaxy. Using microspacecraft and miniature instruments, these new missions will ensure NASA's technological readiness for post-2000 space and Earth science missions.

Begun in fiscal year 1994, New Millennium seeks to miniaturize technologies and send them out on compact spaceships less than half the size of today's spacecraft. These microcraft will be launched so frequently that they will be able to create armadas in space. Some of these probes will combine to create a network of spacecraft capable of discerning trends, examining planetary climates and atmospheres, or landing and studying surface phenomena such as seismic and meteorological activity on a global scale. Other sets of spacecraft could form a constellation uniquely suited to study dynamic, complex extrasolar systems.

These goals require significant changes in almost all aspects of spacecraft design and deployment. New Millennium experimental technology flights will validate key breakthrough technologies required to move toward this goal. Flight validation will accelerate the infusion of these highly advanced technologies into the market place. Some of the new space technologies of tomorrow may become as small and lightweight as a pocket wallet.

Drawing on all sectors of the country's science and technology expertise -- from universities, nonprofit organizations, the aerospace industry and other government agencies to the specialized services of high technology companies -- new technologies will emerge in the next several years that will enable smaller, more autonomous spacecraft to be developed.

The Selection Process

The New Millennium program underscores the need for new technologies that can provide high scientific payoffs and a continuous flow of data from space to Earth. To ensure this goal is met, a science working group representing the fields of planetary science, space physics, astrophysics and terrestrial science has assisted in identifying key challenges facing the scientific community. This group has also catalogued the type of science missions that could conceivably fly in the post-2000 era to address these challenges, as well as the key capabilities that would be required for such missions. Their vision provides the basis for New Millennium's selection of technologies for flight validation.

Technologies to be validated in New Millennium flights will be determined in a three-phase process. In the first phase, identification of a broad suite of technologies is given over to six teams comprising members from private industry, academia, nonprofit organizations, other NASA centers and government agencies, so that they can design roadmaps for the development of breakthrough technologies to meet the science goals of the mission.

NASA calls these groups "integrated product development teams," which are charged with recommending a coherent program of technology development to render the highest priority capabilities currently ready for spaceflight validation. At present six integrated product development teams have been formed in the areas of: 1) spacecraft autonomy; 2) microelectronics systems; 3) in-situ instruments and microelectromechanical systems; 4) instrument technologies and architectures; 5) communications; 6) and modular and multifunctional systems.

Innovative concepts are being sought from all sectors of the engineering and science communities and the technologies will be prioritized by these product development teams. Those technologies designated high priority by the teams are expected to provide revolutionary advances in capability that will allow New Millennium missions to leap ahead in reducing the cost of 21st century space flight. Additional factors considered in identifying these technologies include their applicability to a wide range of missions and their ability to address science goals at an affordable cost.

In the second phase of the selection process, technologies being considered for flight development are further winnowed by assessing their long-term impact on science return, their cost, the revolutionary nature of the technologies and the degree of risk reduction offered by flight validation. Evaluation of the technologies in this phase will be done by program management in consultation with the science working group and flight teams. At the end of this phase, a host of technologies with a corresponding set of flights will be recommended to NASA Headquarters.

The third phase of the selection process involves delivery of technologies for flight. A set of readiness checkpoints will ensure timely delivery of the technologies for flight. Those which meet the schedule of checkpoints will be integrated and flight validated by New Millennium.

Selection of technologies for a particular validation flight will require a match between the development cost and readiness dates of a given technology, in addition to the ability to ready the technology for flight given budget constraints and flight opportunities available for New Millennium. This final step will be carried out by program management, with consideration given to the balance and interrelationships between high priority technologies needed for 21st century science missions.

Facilities and Funding

NASA's Jet Propulsion Laboratory was chosen to manage the New Millennium program in part because of its expertise in developing advanced space technologies. Facilities such as its Microdevices Laboratory place JPL in the forefront of emerging micro-technologies for spaceflight. As a federally funded research and development center, the Laboratory has broad-based funding resources for technology development work.

The Laboratory has reengineered its project design process to reduce the cost of developing a spaceflight mission. Construction of a new Project Design Center at JPL represents a bold new approach in automated mission design and verification. The center is a computer-aided design facility capable of creating several spacecraft designs and options in very little time.

The Laboratory's Flight System Testbed complements the Project Design Center in developing concurrent engineering systems for new spacecraft and identifying incompatibilities early in the design phase.

The space agency's New Millennium program costs $55 million in fiscal year 1996 dollars and is expected to be funded at approximately $75 million in 1997. That budget is likely to increase to about $95 million per year by fiscal year 1998. As part of NASA's national technology pipeline, many of the new technologies being proposed by industry and other organizations in the commercial sector will be flown and validated in future New Millennium flights.

Integrated Product Development Teams

Integrated product development teams have been established in technology areas where a range of significant advances within related fields requires a coordinated approach. These areas are: autonomy; microelectronics systems; in-situ instruments and microelectromechanical systems; instrument technologies and architectures; communications; and modular and multifunctional systems.

Teams are made up of anywhere from seven to 16 members. Roughly half of the members come from NASA and other government agencies and were selected by NASA itself. The other half were selected through an open competition with industry, nonprofit laboratories and academia based on the technology concepts that were proposed, in addition to their relevance to New Millennium objectives and the stage of maturity of these technologies.

The six integrated product development teams will address the following areas:

❏ The autonomy team will focus on software and end-to-end system architecture that enables autonomous spacecraft operation, thereby reducing the ground operations costs. Technologies of interest include real-time and fault tolerant spacecraft systems; those technologies which can guarantee fault detection, isolation, recovery and avoidance; products such as computer-aided software engineering tools and knowledge-based software; and tools for advanced software architecture.

These technologies will support functions such as overall mission control, spacecraft sequencing, spacecraft health and resource management, payload data collection and analysis, guidance and navigation. These systems will also support station-keeping of multiple spacecraft and be capable of managing and disseminating spacecraft information and data.

❏ The microelectronics team will develop the technology for an integrated, three-dimensional microelectronics architecture that will replace a spacecraft's avionics functions, which are provided by separate individual subsystems such as attitude control, command and data processing, power and mass data storage.

Such integrated architectures can improve system performance while drastically reducing the mass and power requirements, and eliminating many discrete components and external interfaces. Enhanced performance will support information processing onboard spacecraft, giving them more autonomy and the capability of working in concert with several other spacecraft forming a constellation in orbit.

❏ The in-situ instruments and microelectromechanical systems team will focus on revolutionary advances in science instruments and miniature electrical and mechanical devices that offer new and affordable approaches to collecting science data or to providing spacecraft engineering data.

Sensors the size of a computer chip and integrated instrument packages will be developed to enable new capabilities and reduce component sizes and costs. New approaches for designing, simulating and packaging novel microinstrument technologies will also be addressed.

❏ The instrument technologies and architectures team will define technology validation for new instruments and combine them in a system architecture that reduces the cost of science measurements and makes possible the acquisition of new science measurements.

❏ The communications team will develop small, highly integrated modular telecommunications systems for deep space and near-Earth spaceflight missions. Deep space and near-Earth missions require advances in ultra low noise and ultra high bandwidth capabilities, respectively. Innovations will be necessary to increase efficiency in higher frequency radio systems, to share transceiver hardware with navigation and science data acquisition and to implement new approaches in data coding and operational concepts.

❏ The modular and multifunctional systems team will address revolutionary advances in mechanical and thermal systems, energy generation and storage, and propulsion alternatives that offer affordable solutions for science missions in the next century. New approaches will be developed to reduce the structural mass of spacecraft and to use solar electric power even in missions that take place far from the Sun.

Team Members

AUTONOMY:
NASA Ames Research Center, Mountain View, CA
Air Force Phillips Laboratory, Albuquerque, NM
ISX Corporation, Westlake Village, CA
TRW, Redondo Beach, CA
OCA Applied Optics, Garden Grove, CA
NASA Goddard Space Flight Center, Greenbelt, MD
LSMC Palo Alto Research Laboratory, Palo Alto, CA
Carnegie Mellon University, Pittsburgh, PA
Hughes Danbury Optical Systems, Danbury, CT
Stanford University, Palo Alto, CA

MICROELECTRONICS:
Lockheed Martin Astro Space, Princeton, NJ
Georgia Institute of Technology, Atlanta, GA
Loral Federal Systems, Manassas, VA
NASA Goddard Space Flight Center, Greenbelt, MD
TRW, Redondo Beach, CA
Massachusetts Institute of Technology Lincoln Laboratory, Lexington, MA
Air Force Phillips Laboratory, Albuquerque, NM
University of California, San Diego, CA
University of Southern California, Los Angeles, CA
Honeywell, Inc., Clearwater, FL
NASA Lewis Research Center, Cleveland, OH
Space Computer Co., Santa Monica, CA
Optivision, Palo Alto, CA
Boeing, Seattle, WA
Sandia National Laboratory, Albuquerque, NM

IN-SITU INSTRUMENTS AND MICROELECTROMECHANICAL SYSTEMS:
Air Force Phillips Laboratory, Albuquerque, NM
Southwest Research Institute, San Antonio, TX
Los Alamos National Laboratory, Los Alamos, NM
Stanford University, Palo Alto, CA
Sandia National Laboratory, Albuquerque, NM
National Science Foundation, Washington, DC
Defense Advanced Research Projects Agency, Washington, DC

INSTRUMENT TECHNOLOGIES AND ARCHITECTURES:
SSG, Inc., Waltham, MA
University of Massachusetts, Amherst, MA
Lockheed Sanders, Nashua, NH
TRW, Redondo Beach, CA
NASA Goddard Space Flight Center, Greenbelt, MD
Hughes Aircraft/Santa Barbara Remote Sensing , Goleta, CA
Massachusetts Institute of Technology Lincoln Laboratory, Lexington, MA
Orbital Sciences Corporation, Pomona, CA
Southwest Research Institute, Boulder, CO and San Antonio, TX
Optical Sciences Center, University of Arizona, Tucson, AZ
University of Wisconsin, Madison, WI
Rochester Institute of Technology, Rochester, NY
NASA Langley Research Center, Hampton, VA
NASA Marshall Space Flight Center, Huntsville, AL
ITT, Fort Wayne, IN
Ball Aerospace, Boulder, CO

COMMUNICATIONS:
NASA Lewis Research Center, Cleveland, OH
Lockheed Martin Astro Space Corp., Philadelphia, PA
Boeing Co., Seattle, WA
Loral Space Systems, Palo Alto, CA
University of Michigan at Ann Arbor, MI
TRW, Redondo Beach, CA
NASA Goddard Space Flight Center, Greenbelt, MD

MODULAR ARCHITECTURES AND MULTIFUNCTIONAL SYSTEMS:
NASA Langley Research Center, Hampton, VA
NASA Goddard Space Flight Center, Greenbelt, MD
Air Force Phillips Laboratory, Albuquerque, NM
Lockheed Martin Astronautics Corporation, Denver, CO
L'Garde, Inc., Tustin, CA
Olin Aerospace Company, Redmond, WA
Massachusetts Institute of Technology, Cambridge, MA
Yardney, Pawcatuck, CT
University of Colorado, Boulder, CO
SSG, Inc., Waltham, MA
NASA Lewis Research Center, Cleveland, OH
University of Arizona, Tucson, AZ

Teaming with NASA

The New Millennium program has actively solicited and will continue to solicit the participation of industry, universities, nonprofit organizations, NASA centers and other government agencies to form innovative relationships within these integrated product development teams. The integrated product development teams will identify, develop and deliver the breakthrough technologies for specific missions.

Concurrent engineering teams will be assembled to carry out flight and ground-system engineering for each New Millennium flight. All categories of players will be eligible to participate as members of any of these teams.

Universities that are prepared to deliver flight hardware or software can compete directly for membership in an integrated product development team or they can team with an industrial organization that already has membership in a team. Universities will also be major participants in NASA's Miniature Spacecraft Technology program, which supports the objectives of New Millennium. This and similar technology development programs under the sponsorship of other government agencies are part of the nation's technology pipeline from which New Millennium will select its technologies for flight validation.

Small businesses that are ready to develop and deliver hardware and software can become members of the integrated product development teams in the same way as universities. They are also eligible for funding to develop relevant technologies through NASA's Small Business Innovation Research program.

A number of government sponsors, including the U.S. Air Force Phillips Laboratory, the Defense Advanced Research Projects Agency and the National Science Foundation, have expressed an interest in coordinating their technology development programs to match those of New Millennium and other NASA technology development programs currently in place. The synergy created by these pooled resources and expertise offers benefits to all parties.

Some government agencies already hold membership in some of the integrated product development teams. The technologies they are developing can be carried out in government, nonprofit, industrial or academic laboratories. Some government laboratories, such as the Department of Defense or the Department of Energy, may participate in specific New Millennium missions, contributing to such activities as mission/trajectory design and navigation, spacecraft instrumentation, fabrication or testing, and mission operations.

Deep Space 1

The first of three deep space missions to be flown by the year 2000 under the New Millennium program features a 350-kilogram (770-pound) spacecraft to be launched in July 1998 and fly by an asteroid named McAuliffe and, subsequently, a comet called West-Kohoutek-Ikemura.

New Millennium's Deep Space 1 mission will demonstrate a variety of advanced technologies that will help enable many ambitious deep space and Earth-orbiting missions planned for flight early in the next century. The spacecraft will also be the first to rely on solar electric propulsion for its main source of thrust, rather than conventional solid or liquid propellant-based systems.

Spectrum Astro Inc. of Gilbert, AZ, has been selected as the primary industrial partner on the first mission team. David Lehman of JPL is the mission team leader.

Technologies likely to be demonstrated include new telecommunications equipment, advanced solar arrays and a miniaturized camera and imaging spectrometer that takes pictures of and makes chemical maps of the target asteroid and comet. New mission operations techniques will give the spacecraft independent decision-making abilities that are unprecedented for such a deep space mission.

The spacecraft will be powered by a xenon ion engine, built at Hughes Electron Dynamics Division in Torrance, CA. In space, the 30-centimeter-diameter (11.8-inch) engine will use the heavy but inert xenon gas as propellant and be driven by more than 2,000 watts from large solar arrays provided by the Ballistic Missile Defense Organization. The actual thrust comes from accelerating and expelling the positively charged atoms, called ions. The thrusting action is similar to that of chemical propellant engines which expel burning gases, except that such engines can produce up to millions of pounds of thrust. Deep Space 1 carries 66 kilograms (145 pounds) of xenon and is launched on the smallest member of the Delta family of launch vehicles. Without the tremendous capability of the ion propulsion, to accomplish the same mission would require a larger (more expensive) launch vehicle and more than 500 kilograms (1,100 pounds) of chemical propellant.

An ion engine, however, starts with only about 90 millinewtons (20-thousandths of a pound) of thrust. The engine does not roar but just emits an eerie blue glow. While atoms, charged by an electric arc which removes one of the 54 electrons around their nuclei, are fired in great numbers out the thruster at more than 31 kilometers per second (70,000 miles an hour), their accumulative mass is so low that the spacecraft accelerates very slowly but over many months builds up to very high speed. Still, ion propulsion is far more efficient a propellant than is chemical propulsion.

Deep Space 2

Two small science probes, weighing less than 2 kilograms (4.5 pounds) each, will be sent to Mars in 1999 aboard the 1998 Mars Surveyor lander to study Mars' soil and atmosphere.

The microprobes will be designed to withstand both very low temperatures and high decelerations. Each highly integrated package will include a command and data system, a telecommunications subsystem, power microelectronics with mixed digital/analog integrated circuits, an ultra low-temperature lithium battery, a microcontroller and flexible interconnects for system cabling.

In-situ instrument technologies for making direct measurements of the Martian surface will include a meteorological pressure sensor and a temperature sensor for measuring thermal properties of the Martian soil and a soil collection and analysis instrument.

The microprobes will be mounted on the 1998 Mars Lander's cruise ring. The probes will separate and plummet to the surface using a single-stage entry aeroshell system. Upon impact, the aeroshells will shatter and the microprobes will split into a forebody and aftbody system. The forebody, which will be lodged 30 to 184 centimeters (1 to 6 feet) underground, will contain the primary electronics and instruments. The aftbody will stay close to the surface to collect meteorological data and deploy an antenna for relaying data back to Earth.

Just announced in July 1996, NASA will work in the next several months to select industrial partners who will help develop the microprobes and a variety of advanced technologies to demonstrate during the mission. The mission is lead by Sarah Gavit, microprobe flight team leader at JPL.

Earth-Orbiting Mission

An advanced, lightweight scientific instrument designed to produce visible and short-wave infrared images of Earth's land surfaces was selected as New Millennium's first Earth-observing mission. As the first in the New Millennium program's series of Earth-observing missions, the spaceborne imager flight will be managed by NASA's Goddard Space Flight Center, Greenbelt, MD, as part of NASA's Mission to Planet Earth program.

The instrument will serve multiple purposes, such as providing remote-sensing measurements of Earth that are consistent with data collected since 1972 by the Landsat series of satellites, which is used by farmers, foresters, geologists and city planners. In addition, it will acquire data with finer spectral resolution, a capability long sought by many scientists studying Earth and its environs, and it will lay the technological groundwork for inexpensive, more compact imaging instruments in the future.

The advanced land imager will be developed from instrument technologies proposed by members of the New Millennium integrated product development teams. The industry teams will be led by the Massachusetts Institute of Technology's Lincoln Laboratory, Lexington, MA, a federally funded research and development center.

The instrument will feature a 10-meter (32-foot) ground resolution in the panchromatic (black-and-white) band and 30-meter (98-foot) ground resolution in its other spectral bands, using a four-chip multispectral focal plane array that covers seven of the eight bands of the current Landsat. Hyperspectral capabilities, which further split these bands into highly differentiated images, will be tested to show that they can be combined into traditional data sets equivalent to Landsat data.

Scheduled for launch in late 1998, the spacecraft will be furnished by Swales & Associates, Inc., Beltsville, MD, and Litton Industries, College Park, MD. The spacecraft will also incorporate other advanced spacecraft technologies made available through New Millennium product development teams.

Program Team

New Millennium's deep space exploration and Earth-observing missions are managed by the Jet Propulsion Laboratory for NASA's Offices of Space Science, Space Access and Technology, and Mission to Planet Earth, Washington, DC.

At JPL, Kane Casani is New Millennium program manager. Dr. Barbara Wilson is deputy program manager for the deep space missions and Dr. Ellen Stofan is the program scientist. Dr. Fuk Li of JPL is deputy program manager for the Earth-observing missions.

Leading the Deep Space 1 flight team is David Lehman of JPL. Sarah Gavit, also of JPL, is flight team leader for the Deep Space 2 mission, which will send a set of microprobes to Mars.

NASA's Goddard Space Flight Center, Greenbelt, MD, will take the lead in launching the first three Earth-observing missions of New Millennium for NASA's Offices of Space Flight, Space Access and Technology, and Mission to Planet Earth, Washington, DC. Dale Schulz of Goddard is flight team leader for the advanced lander imager.

9-96 DEA